Encyclopedia of Sustainability Science and Technology

Robert A. Meyers (Ed.)

Encyclopedia of Sustainability Science and Technology

With 5917 Figures and 1553 Tables

Springer

Editor
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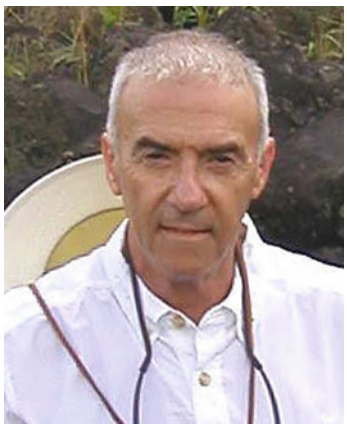
Preface



Editor in chief Bob Meyers at the Aranal Volcano in Costa Rica

Our team consisted of nearly 1,000 chemists, biologists, environmentalists, agronomists, physicists, mathematicians, and engineers who have prepared, supervised, or peer reviewed the content of this *Encyclopedia*. Our magnum opus is a 18-volume 12555-page resource available in both print and online, of over 550 peer-reviewed, detailed articles defining the science and technology basis for providing for the sustainability of the earth as global population and the needs of that population increase dramatically. We plan to continually update our articles as new technology and data become available such that this *Encyclopedia* will remain the most up-to-date compendium of sustainability science and technology available. This encyclopedic treatment has been prepared by scientists and engineers for other scientists and engineers as well as planners and evaluators, in a format which allows experts in one field to easily understand detailed treatments of fields not within their area of expertise. These entries form a scientific basis for the huge volume of sustainability evaluations and studies as well as research and business decisions, being performed within thousands of institutions worldwide. This new *Encyclopedia* is a natural follow-on and is symbiotic with our recently completed *Encyclopedia of Complexity and Systems Science*, which provides key mathematical and modeling tools for understanding such diverse complex systems as cosmology, earthquakes, volcanoes, tsunamis, molecular biology, traffic management, and robotics as well as econometrics and sustainability of the earth.

We have established an advisory board of nineteen of the most prominent experts in sustainability which includes five Nobel Laureates and a co-recipient of the Nobel Peace Prize for climate change research, as well as a group of 41 section editors who have overseen the content of each of the 38 topical areas and coordinated the near 1,000 authors and peer reviewers who prepared and reviewed the entries.

The content of the *Encyclopedia* includes:

- Solar energy (thermal, photovoltaic, thermal electric)
- Renewables (wind, ocean thermal, biomass, ethanol, and other biofuels)
- Geothermal
- Fossil energy technologies (extraction, production, storage, transport)
- Nuclear energy
- Electrical generation and transmission

- Green chemistry and engineering
- Transportation
- Conservation
- Science and technology of the sustainable built environment
- Pollution sources, statistics, measurement, and control
- Natural resources
- Food production and technology
- Oceans farming and oceans and human health
- Fresh water resources, water purification, and desalinization
- Social ecological systems
- Biological ecological systems
- Green practices
- Climate change data, mitigation, and modeling
- Earth system monitoring
- Earth system modeling and economics
- Health and infectious diseases and epidemiology

This list of topics clearly sets our project apart from compendia and publications which now exist, in both extent and depth. In fact, current compendia of the science and technology of several of these topics do not presently exist and yet the content is crucial to any evaluation and planning for the sustainability of the earth.

Vital scientific issues include: human and animal ecological support systems, energy supply, and effects; the planet's climate system; systems of agriculture, industry, forestry, and fisheries; the ocean, fresh water, and human communities; waste disposal, transportation, and the built environment in general and the various systems on which they depend; and the balance of all of these with sustainability. In this context, sustainability is a characteristic of a process or state that can be maintained at a certain level indefinitely even as global population increases toward 9 billion by 2050. The population growth, and the hope for increase in wealth, implies something like a 50% increase in food demand by as early as 2030. At the same time, the proportion of the population that lives in an urban environment will go up from about 47 to 60%. Global economic activity is expected to grow 500%, and global energy and materials use is expected to increase by 300% over this period. That means there are going to be some real problems for energy, agriculture, and water, and it is increasingly clear that conflicting demands among biofuels, food crops, and environmental protection will be difficult to reconcile. The "green revolution" was heavily dependent on fertilizers which are manufactured using increasingly expensive and diminishing reserves of fossil fuels. In addition, about 70% of available freshwater is used by agriculture. Clearly, many natural resources will become either depleted or scarce relative to population. This *Encyclopedia* is founded on two major assumptions. First, we acknowledge that any true measure of sustainability must include some consideration of the number of people to be supported and at what standard of living. In this respect, population is a linchpin in attempts to understand and achieve sustainability. While top-down approaches to controlling population growth, maintaining biodiversity, etc., certainly do exist, science and technology and the resulting innovation economy is a bottom-up affair involving individuals and teams of individuals in publicly funded scientific laboratories and private corporations. This process is essentially unpredictable, resulting in a great range of promising technologies that are individually dwarfed by the scope of the challenge but represent essential contributions to sustainability.

While there are many Web-based and even some print encyclopedic treatments of sustainability science in the broad sense, none are comprehensive and rise to the university or professional scientist and engineer level needed to support real progress from the bottom up. The emphasis for the *Encyclopedia of Sustainability Science and Technology* team is on science and technology and not on policy and positions. Rather, this *Encyclopedia* is a comprehensive and authoritative resource for policy makers who want to understand how scientific and technological innovations

in all fields map onto the true scope of the sustainability challenge and will also be a major resource for scientists and engineers in developing new technologies and for applying existing technologies to sustainability. Further, we plan to maintain our 1,000-scientist and engineer team to continually update our content.

Among the topics covered are: the chemistry, physics, modeling, and engineering of green chemistry for industry, water use, and recovery; crop production including precision farming, genetic modification of crops, with forest maintenance; all types of energy production, electric utility as well as small-scale electric generation (fossil fuel as well as nuclear fission and fusion, solar electric and thermal and renewable) and mass and personal transportation with fuel modification, power source variation, pollution control, and waste disposition; solid waste utilization, recycle, and disposition; urban planning and the built environment; environmental quality; engineering mitigation, adaptation, and forecasting of global warming, and any possible cooling due to solar-earth insolation dimming; geoengineering and greenhouse effect mitigation measures; measurement and observation systems (terrestrial and from space); analytical chemistry methods for the biosphere, including indoor pollution and industrial hygiene; disease prevention and treatment; and catastrophic event (e.g., volcanic eruption, tsunamis, cyclones, tornadoes) measurement and mitigation.

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Robert A. Meyers
Editor in Chief
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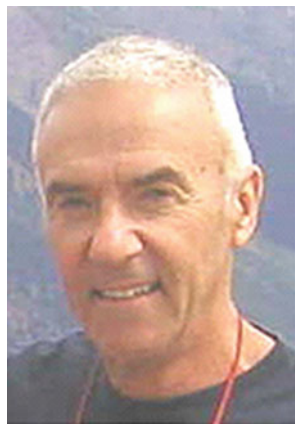

Robert A. Meyers
Dr. Meyers has just completed serving as editor in chief for the Springer *Encyclopedia of Complexity and Systems Science*
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Dr. Meyers has worked with more than 20 Nobel laureates during his career. The photo of Dr. Meyers at the Continental Divide was taken during a tour of Colorado earth sciences, environmental and solar energy facilities.

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RESEARCH
Dr. Meyers was manager of Energy and Environmental Projects at TRW (now Northrop Grumman) in Redondo Beach, CA, and is now president of RAMTECH Limited. He is coinventor of the Gravimelt process for desulfurization and demineralization of coal for air pollution and water pollution control and was manager of the Department of Energy project leading to the construction and successful operation of a first-of-a-kind Gravimelt Process Integrated Test Plant. Dr. Meyers is the inventor of and was project manager for the DOE-sponsored Magnetohydrodynamics Seed Regeneration Project which has resulted in the construction and successful operation of a pilot plant for production of potassium formate, a chemical utilized for plasma electricity generation and

air pollution control. He also managed TRW efforts in magnetohydrodynamics electricity generating combustor and plasma channel development. Dr. Meyers managed the pilot-scale DoE project for determining the hydrodynamics of synthetic fuels. He is a coinventor of several thermo-oxidative stable polymers which have achieved commercial success as the GE PEI, Upjohn Polyimides, and Rhone-Polenc bismaleimide resins. He has also managed projects for photochemistry, chemical lasers, flue gas scrubbing, oil shale analysis and refining, petroleum analysis and refining, global change measurement from space satellites, analysis and mitigation (carbon dioxide and ozone), hydrometallurgical refining, soil and hazardous waste remediation, novel polymers synthesis, modeling of the economics of space transportation systems, space rigidizable structures, and chemiluminescence-based devices.

He is a senior member of the American Institute of Chemical Engineers, member of the American Physical Society, member of the American Chemical Society, and serves on the UCLA Chemistry Department Advisory Board. He was a member of the joint USA-Russia working group on air pollution control and the EPA-sponsored Waste Reduction Institute for Scientists and Engineers.

Dr. Meyers has more than 20 patents and 50 technical papers in the fields of photochemistry, pollution control, inorganic reactions, organic reactions, luminescence phenomena, and polymers. He has published in primary literature journals including *Science* and the *Journal of the American Chemical Society*, and is listed in *Who's Who in America* and *Who's Who in the World*. Dr. Meyers' scientific achievements have been reviewed in feature articles in the popular press in publications such as *The New York Times Science Supplement* and *The Wall Street Journal* as well as more specialized publications such as *Chemical Engineering* and *Coal Age*. A public service film was produced by the Environmental Protection Agency of Dr. Meyers' chemical desulfurization invention for air pollution control.

SCIENTIFIC BOOKS

Dr. Meyers is the author or editor in chief of 12 technical books including the *Handbook of Chemical Production Processes*; *Handbook of Synfuels Technology and Handbook of Petroleum Refining Technology (McGraw-Hill)*; *and The Handbook of Energy Technology and Economics*, published by John Wiley & Sons*; Coal Structure*, published by Academic Press; and *Coal Desulfurization* as well as the *Coal Handbook* published by Marcel Dekker. He served as chairman of the advisory board for *A Guide to Nuclear Power Technology*, published by John Wiley & Sons, which won the Association of American Publishers Award as the best book in technology and engineering.

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Dr. Meyers conceived and has served as editor in chief of the Academic Press (now Elsevier) *Encyclopedia of Physical Science and Technology*. This is an 18-volume publication of 780 twenty-page articles written to an audience of university students and practicing professionals. This encyclopedia, first published in 1987, was very successful, and because of this, was revised and reissued in 1992 as a second edition. The Third Edition was published in 2001 and is now available online. Dr. Meyers has completed two editions of the *Encyclopedia of Molecular Cell Biology and Molecular Medicine* for Wiley VCH publishers (1995 and 2004). These cover molecular and cellular level genetics, biochemistry, pharmacology, diseases, and structure determination as well as cell biology. His eight-volume *Encyclopedia of Environmental Analysis and Remediation* was published in 1998 by John Wiley & Sons and his 15-volume Encyclopedia of *Analytical Chemistry* was published in 2000, also by John Wiley & Sons.

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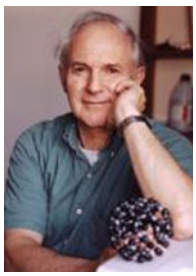

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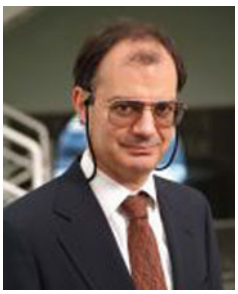

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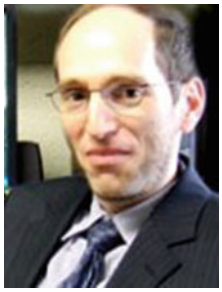

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Each Section Editor prepared an introductory article describing their field, the articles comprising the section and the interrelationship of the articles. Thus, our readership can utilize each section introduction as the reference point to the individual articles or can look up individual articles by alphabetical entry. The introductory articles occur alphabetically, under the section name, among the 578 alphabetically listed entries.